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MONOPULSE SIGNAL PROCESSING AND SIM[JLATION FOR DSN BEAM WAVEGUIDE ANTENNA

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ABSTRACT

NASA's Deep Space Network (DSN) uses both 70-m and 34-m reflector antennas to communicate with spacecraft at S-band and X-band. To improve quality of telecommunication and to meet future spacecraft requirement, JPL has been developing 34-meter Ka-band beam waveguide antennas. Presently, Antenna pointing operates in either open loop mode with blind pointing using navigation predicts or the closed loop mode with conscan Pointing accuracy under normal conscan operation conditions is in the neighborhood of 5 millidegrees. This is acceptable at S and X-band, but not enough at Ka-band. Due to the narrow beam width at Ka-band, it is important to improve pointing accuracy significantly (-2 millidegrees). Monopulse antenna tracking is one scheme being developed to meet the stringent pointing accuracy requirement at Ka-band. Other advantage of monopulse tracking includes low sensitive to signal amplitude fluctuation as well as single pulse processing for acquisition and tracking. This paper presents system modeling, signal processing, simulation and implementation of Ka-band monopulse tracking feed for antennas in NASA/DSN ground stations.

The design of the DSN monopulse pointing system consists of the reflector antenna, the multimode corrugated horn feed, waveguide coupler, monopulse signal processor and other associated RF electronics, see references (1) to (4). The general block diagram is shown in figure 1. Starting at the main reflector, a tapered beam is formed. The HE 11 mode in the corrugated horn is excited to radiate the sum pattern while the TE21 mode waveguide coupler generates the difference pattern, see reference (5). With the assumption of perfect Ka to IF conversion, signal processing starts in the IF domain. Phase locked loop recovers the carrier phase. This is used as a reference to demodulate the elevation and cross-elevation difference channels. The sum and difference baseband signals arc passed on to the monopulse signal processor from which elevation and cross-elevation pointing errors are estimated. The error signals arc used to drive the antenna servo loop for pointing corrections. To predict overall systems performance, an antenna system model is nccdcd, Based on the physics of corrugated horn and mode coupler, the classical four horns monopulse antenna is shown to produce the same open loop S-curve as the monopulse single aperture multimode antenna. i e., the four horns model can be used as a system model for a single aperture mult imodc antenna.

Next, the antenna pointing simulation is developed under the four horns model. It is constructed on the platform of the COMDISCO's Signal Processing Work system (SPW). Simulation blocks are chosen from the systems library and they are configured as in figure 1. The following cases are invest igated.

1. Open loop monopulse pointing of single aperture multimode antenna with deterministic source.
2. Closed loop monopulse antenna pointing analysis with deterministic source.
3. Characteristics of open loop single aperture multimode antenna in random noise.

For case 1, pointing error is simulated by introducing signal path delay among horns. The output voltage of the difference channel is recorded. The result can be compared to the mathematics and physics models, see figure 2. It shows that the simulation result closely matched the medium error mathematics as well as the physics model.

For case 2, a crude second order servo loop is used to model the antenna controller. The frequency response has a 3 dB roll-off at 0.1 Hz, see figure 3. Stability of the servo loop is investigated as a function of the low pass filter bandwidths in the forward path. Step response of the loop are simulated, see figure 4. The results show that low pass filter bandwidth used in signal processing have to be about two orders of magnitude higher than the loop bandwidth for stable loop operation.

For case 3, Gaussian noise is introduced at the horns, The signal and noise power are adjusted to yield 20 dB-Hz CNR. Variances of the error voltage and pointing error are calculated by the second moment estimator. Sample value at simulation time of onc second is displayed in figure 5. The error voltage variance follows the inverse SNR relationship as predicted in reference (1). The pointing error standard deviation (1.02 millidegrees) differs slightly from the prediction (1.6 mill lidegrees) due to the more realistic S-curve used in the simulation.

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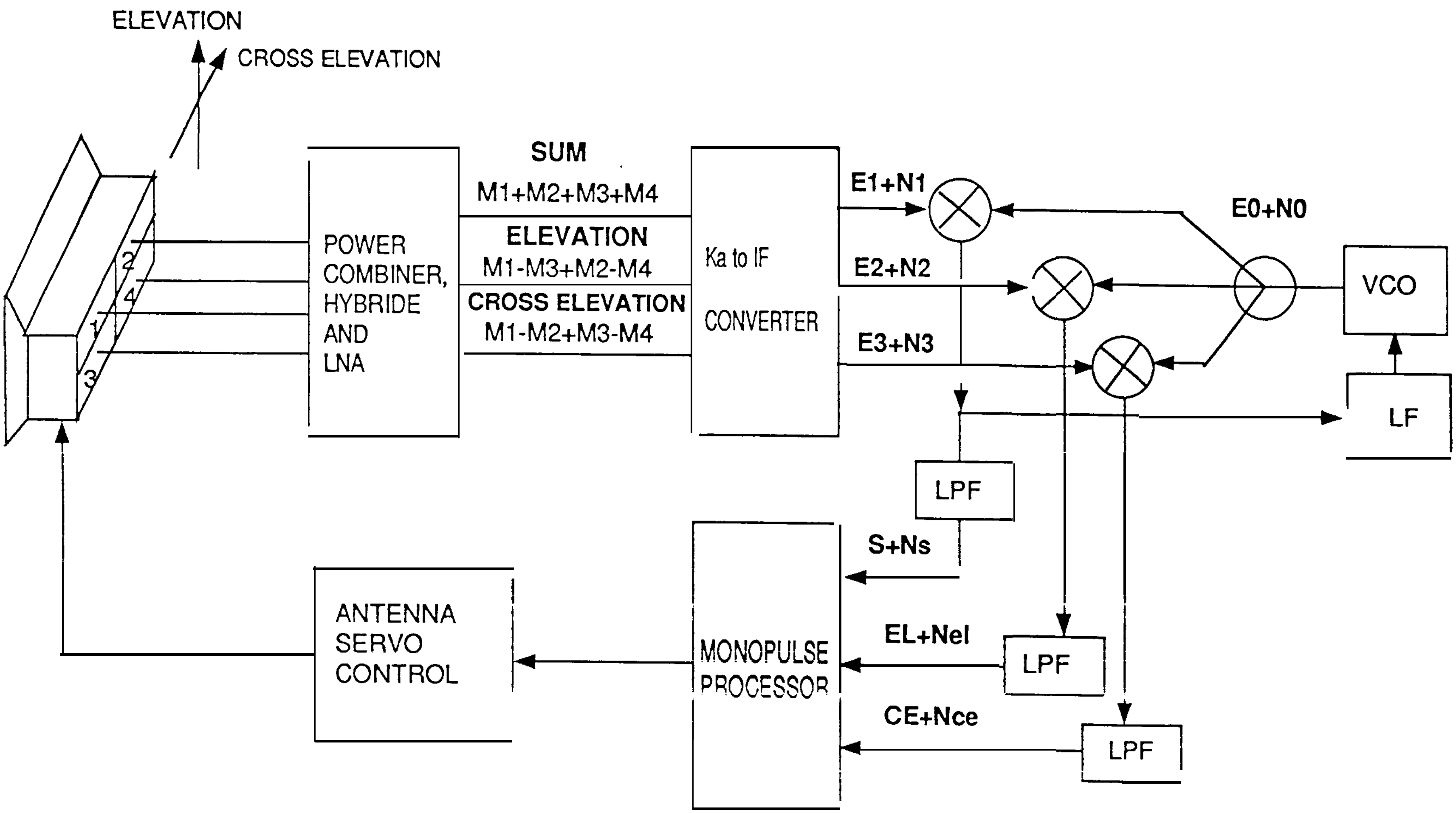
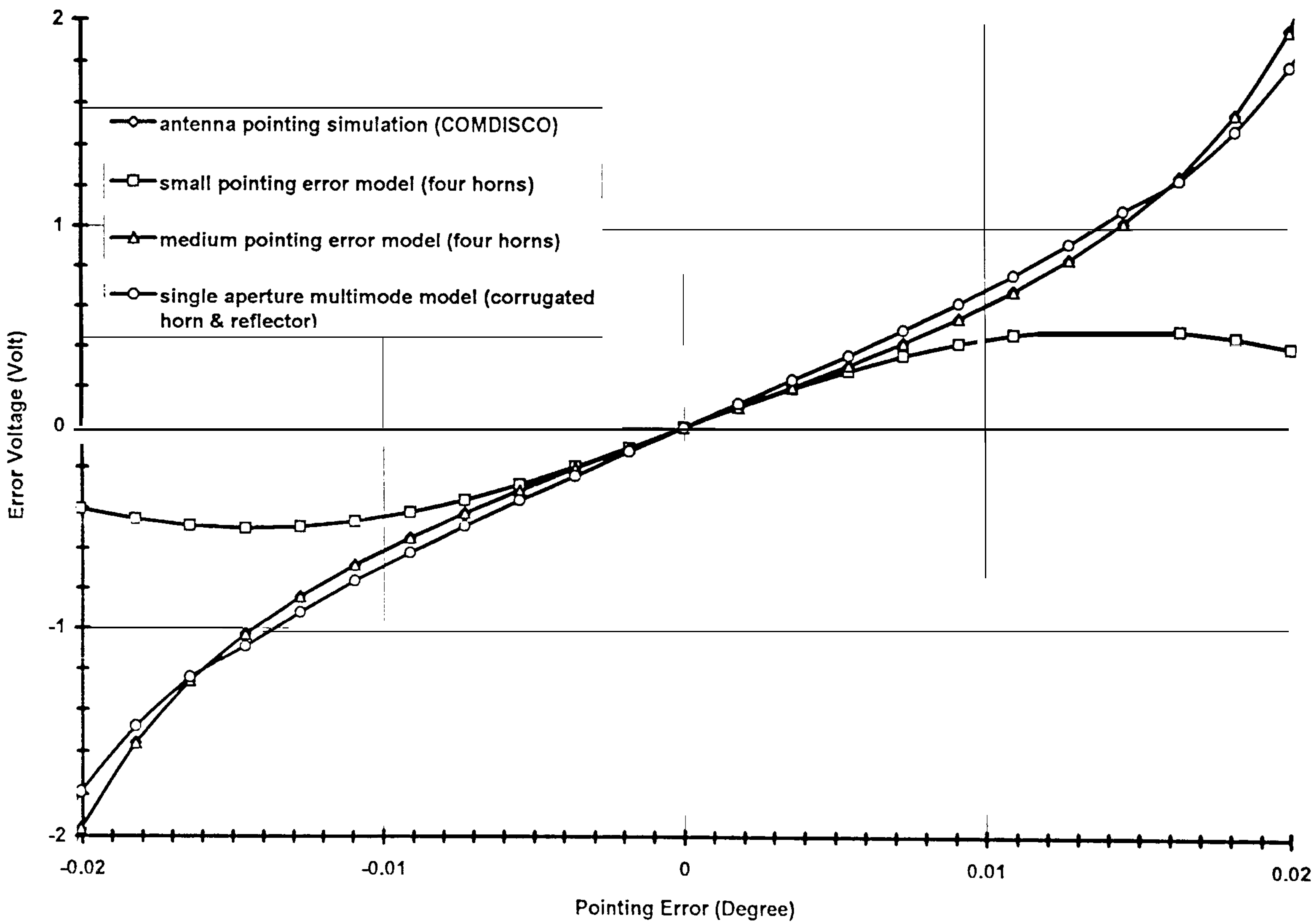


FIGURE 1: ANTENNA POINTING SYSTEM WITH MONOPULSE SIGNAL PROCESSING

FIGURE 2: COMPARISON AMONG SIMULATION, SMALL/MEDIUM POINTING ERROR MODELS AND SINGLE APERTURE MULTIMODE MODEL



Closed Loop Transfer Function:

y/r = [s+1]/[2*s*s + s + 1]

(s*s = s squared)

These are the same for both axes (Az and El)

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                    PI-Controller          Antenna
                    -------------          --------
                   |  ki          |           1    |
r -->(+)-----------| ----  +  kp  |--- ----- ---   |-----------> Y
      (-)          |  s           |           s    |
       ^            -------------          --------

      ---------------------------------------------
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ki=0.5, kp=0.5

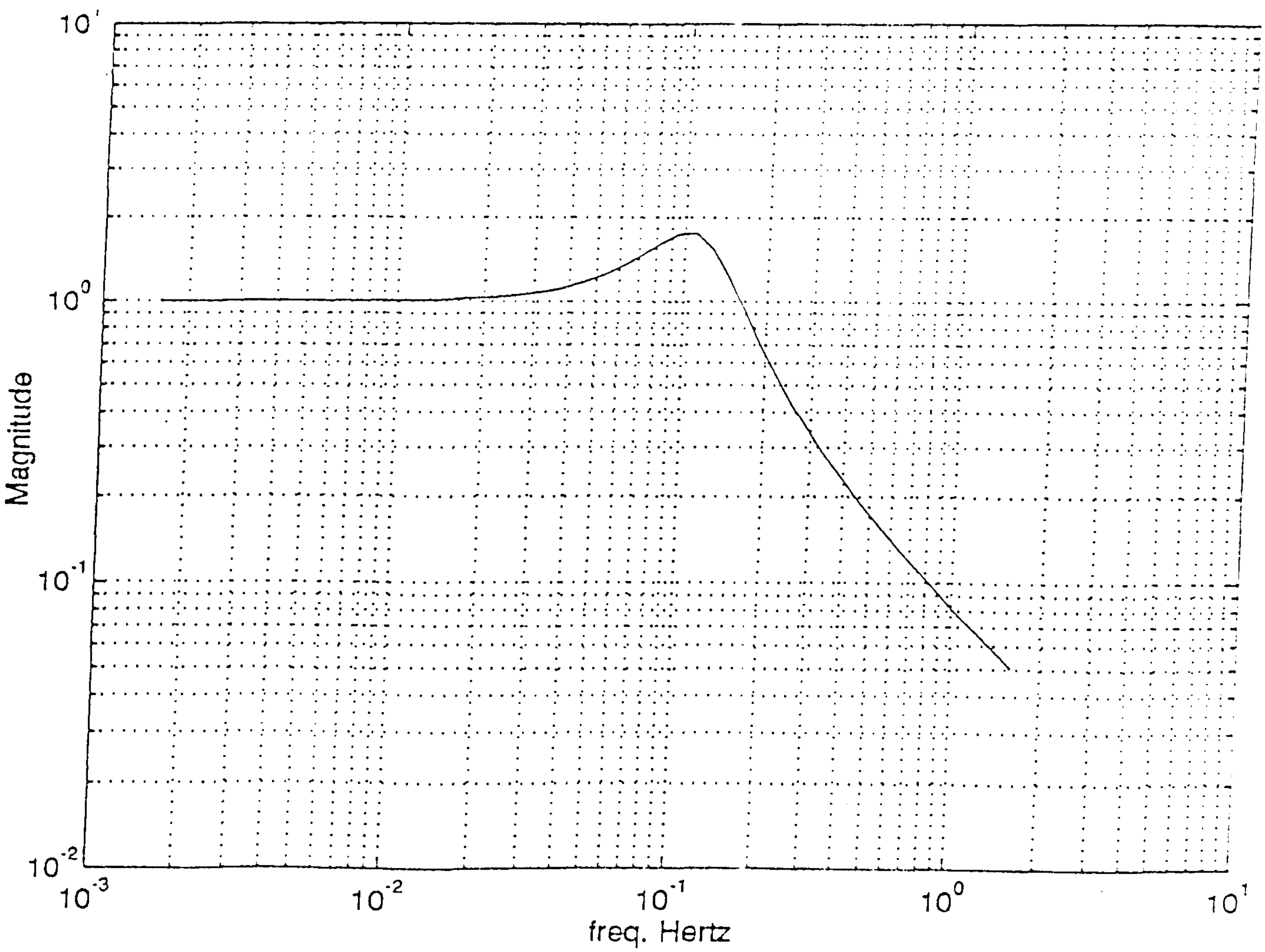

FIGURE 3: CRUDE SECOND ORDER SERVO 1,00P MODEL

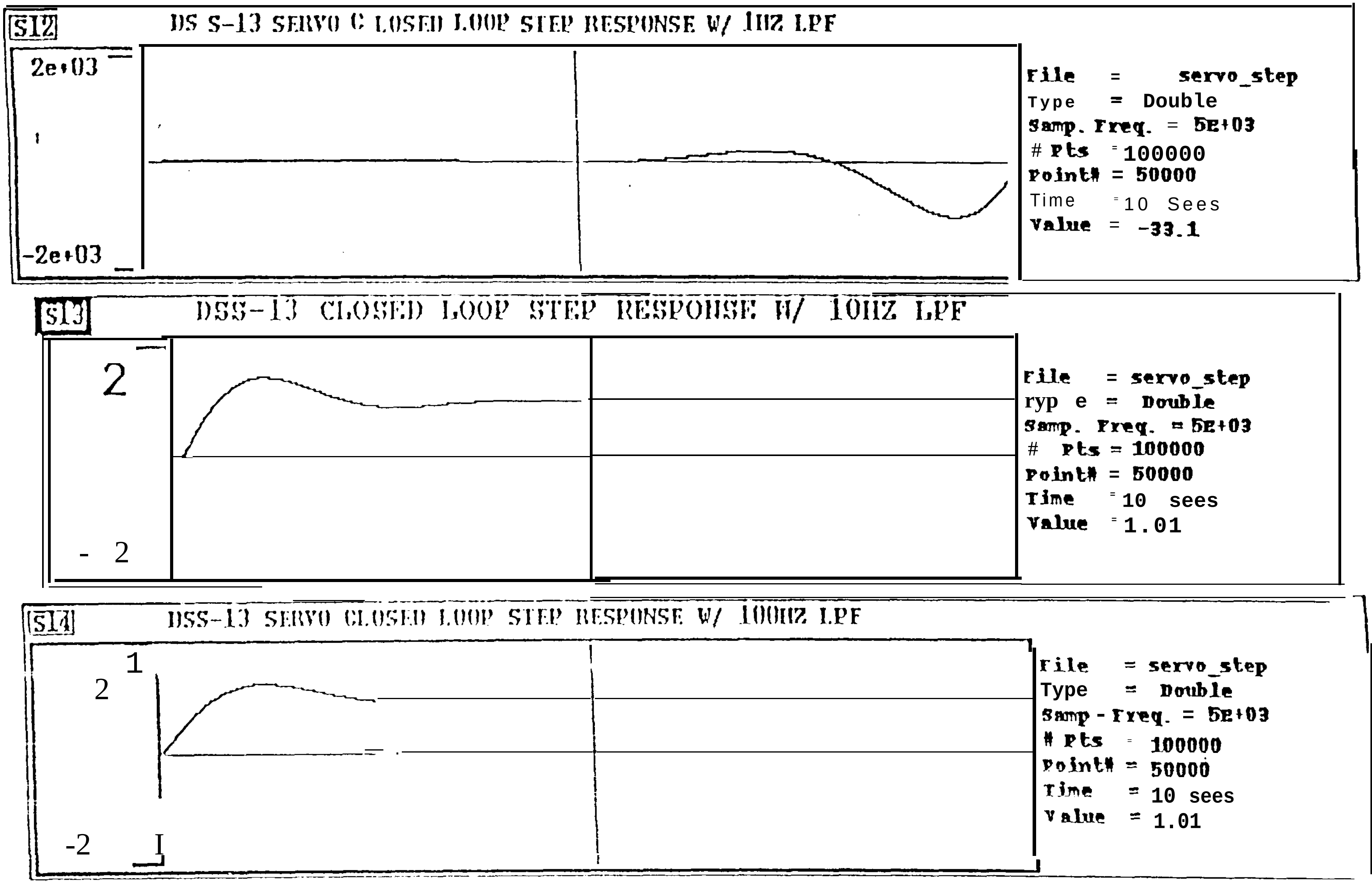

FIGURE 4: SIMULATED CLOSED LOOP STEP RESPONSE OF LPF W/1, 10, 100 HZ BANDWIDTH

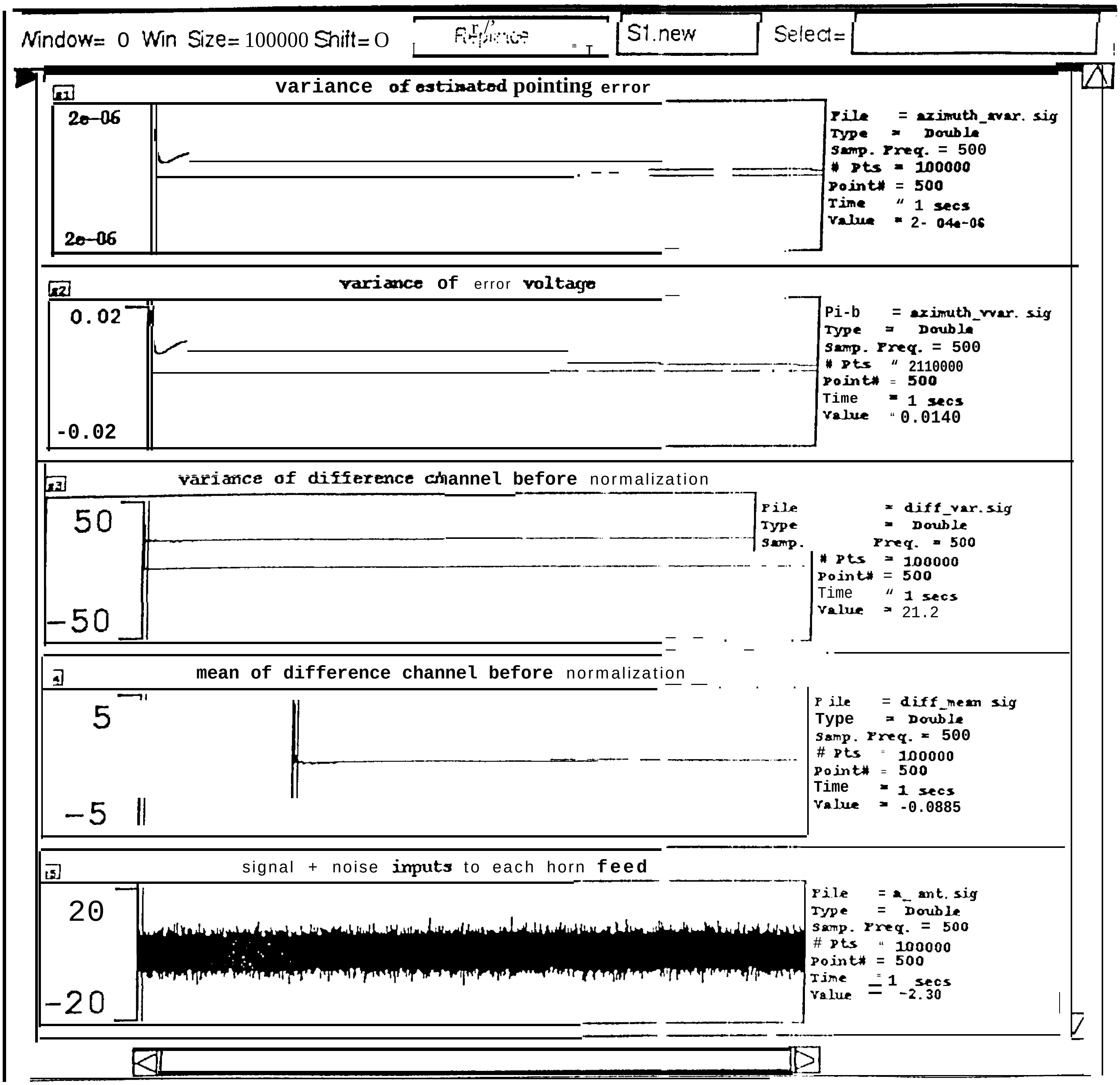

FIGURE 5: SIMULATION OF OPEN LOOP Ka BAND SINGLE APERTURE MULTIMODE ANTENNA POINTING IN GAUSSIAN NOISE